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BIOLOGY AND DESCRIPTION OF IMMATURE STAGES OF *PHIGALIA STRIGATERIA* (MINOT) (GEOMETRIDAE)

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ABSTRACT. Egg, larva, and pupa of *Phigalia strigateria* (Minot) are described for the first time from a population in eastern West Virginia. Eggs were deposited under loose bark of dead twigs. Thirty-two species of trees and shrubs were observed as larval hosts, with preference being shown for oaks, hickories, and common hackberry. Five larval instars and seven larval color forms were noted. Mean developmental time from egg to pupa was 28 days at 24°C.

Four species of North American *Phigalia* belonging to the holarctic tribe Bistonini have been described (Rindge 1975). Three of the species, *P. titea* (Cramer), *P. denticulata* Hulst, and *P. strigateria* (Minot), are found only in eastern North America. Immature stages have been described only for *P. titea* (Butler 1985a, Talerico 1968).

The distribution of *P. strigateria* was given by Rindge (1975) as eastern North America, southern Ontario, and Quebec, from the Atlantic Ocean to about longitude 100°W. While adult *P. strigateria* have been often recorded, almost no information is available on immature stages. Prentice (1963) reported a single larval collection from *Ulmus americana* L. at Brockville, Ontario, in June 1950; he considered the species rare in that locality.

Beginning in 1981, significant defoliation of hardwood forests in eastern West Virginia was attributed to a looper complex. Some larval collections were made in 1982, and a detailed study of the looper complex was conducted in 1983 and 1984. *Phigalia strigateria* was sufficiently abundant to provide material for biological and descriptive studies. Results of these studies are presented here.

Materials and Methods

Study areas were in eastern West Virginia in an oak-hickory-pine forest on dry upland sites. Two study areas were on Cacapon Mountain (Cacapon State Park) in Morgan Co. One area, Batt Picnic Area (Batt), was at 381 m elevation, while the Cacapon Overlook area (Cac) was at 701 m. The Elkhorn Mountain (Elk) area was on the border of Grant and Hardy counties at 732 m elevation. During 1981–82, Batt was 100% defoliated while the other sites were about 25% defoliated. Defoliation in 1983 was greatly reduced because populations collapsed, and by 1984 defoliation was sparse.

Field studies were begun with observations and collections of emerging adult *P. strigateria* on 17 March 1983. Samples of adults were

taken for species confirmation and collection of eggs. Oviposition habits were noted and fecundity was determined by allowing field-collected females to oviposit on dead twigs in the laboratory. All laboratory studies were conducted at 24°C and 12:12 photoperiod. Moths were not provided with food or water as the mouthparts are rudimentary.

Larvae were collected in the field and their host plants recorded. Botanical nomenclature is that of Bailey and Bailey (1976). Stage durations were determined by rearing 60 larvae hatched from eggs laid in laboratory cages. Larvae were reared on leaves of sugar maple in groups of 10 in large Petri dishes. Larvae were checked daily and food was changed every other day. Descriptions were based on both laboratory-reared and field-collected larvae and pupae. Terminology follows Hinton (1946) and McGuffin (1967). Larval head measurements were made with an ocular micrometer; early instars were measured at 30× and later instars at 10×. Illustrations of larvae and pupae are by the author. Voucher specimens of larvae and adults are in the West Virginia University Collection.

RESULTS

Phenology, Life History, Food Plants

In all study areas, the seasonal occurrence of *P. strigateria* was similar to that of *P. titea* (Butler 1985b). Adults were collected at Batt on 17 March 1983 and at the higher altitudes of Cac and Elk beginning 24 March. Males were most often observed resting on tree trunks, while females were climbing tree trunks, resting, or ovipositing on dead twigs. Female *Phigalia* taken at the study sites between 31 March and 26 April were primarily *P. titea*. Females of *P. strigateria* made up the following percentage at each site: Batt 9% (21n), Cac 10% (29n), Elk 8% (26n).

Oviposition habits of *P. strigateria* are similar to those of *P. titea*; eggs are deposited most frequently under loose bark or in cracks or roughened areas of dead hardwood twigs. Females were observed ovipositing in the field on dead twigs of *Acer* spp., *Cornus florida* L., *Quercus* spp., *Betula lenta* L. and *Hamamelis virginiana* L. Field-collected females (9n) lived two to four days in the laboratory and began ovipositing one to two days after being brought from the field. They oviposited a mean of 149 (range 26–319) eggs (9n). Females producing the fewest eggs had probably begun ovipositing before they were collected.

Five larval instars were found for this species; mean developmental time from egg to pupa was approximately 28 days at 24°C (Table 1).

Field larval development was similar to that of *P. titea* (Butler 1985a).

TABLE 1. Development time of *P. strigateria* reared on leaves of sugar maple at 24°C. Means based on 60 larvae.

Instar	Time in instar (days)	
	Mean	Range
1	4.1	3–5
2	3.4	2–4
3	3.4	2–5
4	3.2	2–4
5	7.2	6–9
Prepupa	6.5	5–9
Total	27.8	21–34

Egg hatch in 1983 began about 1 May at the lower altitude at Batt and about a week later at the higher altitudes. Larvae hung down on silk lines and ballooned away from dead twigs on which they hatched. Larvae fed for four to five weeks at each site before they moved into the soil to pupate.

Larval populations at all three study sites in 1983 consisted largely of *P. titea*, ranging from 77 to 94% (2,162n) of the population at Cac and Elk, respectively. Larval percentages of *P. strigateria* at the study sites were: Batt, 4%; Cac, 8%; and Elk, 3%. Other species of larvae present in noticeable numbers were linden looper, *Erannis tiliaria* (Harris), 2–13%; and fall cankerworm, *Alsophila pometaria* (Harris), 1–2%.

Phigalia strigateria larvae were observed feeding on the following 32 hosts:

Juglans nigra L.
Carya ovata (Mill.)
C. tomentosa Nutt.
C. glabra (Mill.)
Betula lenta L.
Corylus americana Marsh.
Quercus alba L.
Q. prinus L.
Q. stellata Wangenh.
Q. rubra L.
Q. coccinea Muenchh.
Q. velutina Lam.
Ulmus rubra Muhlenb.
Celtis occidentalis L.
Hamamelis virginiana L.
Crataegus spp.
Amelanchier canadensis (L.)
A. ×*grandiflora* Rehd.
Malus sylvestris Mill.
M. coronaria (L.) Mill.
Rubus spp.
Prunus serotina Ehrh.
Cercis canadensis L.
Acer negundo L.
A. saccharum Marsh.
A. rubrum L.
A. pensylvanicum L.
Tilia americana L.
Parthenocissus quinquefolia (L.) Planch.
Nyssa sylvatica Marsh.
Cornus florida L.
Vaccinium augustifolium Ait.

Host plants of *P. strigateria* are similar to those of *P. titea* (Butler 1985b).

Favored host plants appeared to be oaks, hickories, and hackberry. Only on hackberry was the percentage of *P. strigateria* larvae within the looper population markedly different from that previously mentioned; *P. strigateria* larvae appeared to make up 40–70% of the looper population on hackberry observed at Batt and Elk.

During 1983, high rates of parasitism by tachinids, ichneumonids, and braconids were observed in field-collected larvae of all four geometrid species. Parasitism was highest for *P. strigateria*, however, reaching 70–90% (135n) in some larval collections. While populations of all looper species in the study areas showed a dramatic collapse in 1983, the collapse of *P. strigateria* was especially notable. In 1984, no adult *P. strigateria* were found, and larvae made up less than 0.01% (250n) of the population at each site.

Description of Immature Stages

Eggs. Eggs are sculptured, slightly rough textured, and oblong, with one end broadly rounded or blunt and the other end conical. They are yellow, becoming duller just before hatching. Empty *P. strigateria* chorions are a pale golden yellow in contrast to those of *P. titea* which are pale lavender. Eggs laid in the laboratory by field-collected females had a mean length of 0.75 mm (range 0.66–0.79) and mean width of 0.45 mm (range 0.40–0.50) (80n).

Larvae. Instars 1 through 3 are uniform in color. Larvae of the last two instars show much variability. The following descriptions are of coloration and mean head widths of instars of the most abundant color form of *P. strigateria*.

Instar 1 (26n): Head (0.27 mm) pale yellow-brown; ground color of body pale greenish tan; pinnaculae black surrounded by white cuticle. Broad diffuse dorsal stripes and broad irregular lateral stripes are greenish white. Cervical shield pale brown; lateral shields of anal prolegs brown, prominent.

Instar 2 (8n): Head (0.50 mm) pale yellow-brown with reddish brown granulations. Ground color of body dark greenish black. Pinnaculae not prominent; setae near spiracles each on a small white chalaza. Dorsal stripes greenish white, prominent when viewed with magnification, but very fine, irregular, and broken. Greenish white subdorsal and lateral stripes just above and below spiracle with diffuse grayish white fill around spiracle. Lateral stripe most prominent on abdominal segments 1–6. Ventral proleg greenish black. Anal plate grayish white with greenish black maculations; anal proleg shields prominent, color of ground, contrasting with paler color of anal segment. Mid-ventral pale stripe expanded at middle of each sternite. Secondary setae are present for the first time in this instar.

Instar 3 (33n): Similar to instar 2. Head (0.81 mm) reddish brown. Dorsal and lateral stripes more prominent. Lateral stripe yellowish, extending down ventral proleg; absent beyond sixth abdominal segment. Anal plate and prolegs pale tan with brownish maculations.

Instar 4 (25n): Head capsule (1.36 mm) yellow, roughened with reddish brown maculations; thoracic legs reddish brown; body ground color black. Dorsal stripes yellow, fine, irregular, often not continuous; black fill frequently between stripes but not consistent; stripes most prominent on abdominal segments 1–2 and 6–9. Dorsal chalazae of eighth abdominal segment most prominent. Lateral stripe irregular, yellow, generally broad and most prominent on abdominal segments 1–6, weak on thorax; on abdominal segment 6, stripe extends down proleg and terminates; lateral striping on posterior abdominal segments appearing only as yellow flecks. Spiracles with black peritreme; spiracular valve yellow. Cervical shield black with brownish tan irregular fill. Anal and

TABLE 2. Percentage of color forms of 4th and 5th instar *P. strigateria* collected between 17 May and 8 June 1983.

Study site	No. larvae	Percentages						
		Typical	Dark	Pale	Yellow/ stripe	Yellow	Orange	Brown
Batt	97	69	1	16	11	2	0	1
Cac	139	35	5	19	26	7	6	2
Elk	60	40	0	19	18	5	18	0

proleg shields prominently mottled yellow-brown. Venter yellowish brown with pale yellow mid-ventral stripe.

Instar 5 (34n): Head capsule (2.24 mm) as in instar 4. Legs tan and dark brown. Dorsal stripes well developed on first nine abdominal segments, partially developed on metathorax, as dashes only on mesothorax, absent on prothorax; stripes yellow, often giving a chain-link appearance dorsally. Cervical shield and anal prolegs granulate dull brown; anal plate pale tan with small, dark maculations. Venter with a broad tan stripe expanded on each segment; stripe on abdominal sternites 7–8 often paler. Other features similar to those of 4th instar.

The most frequently observed variations in color patterns of instars 4 and 5 were the pale form and yellow form with subdorsal stripe.

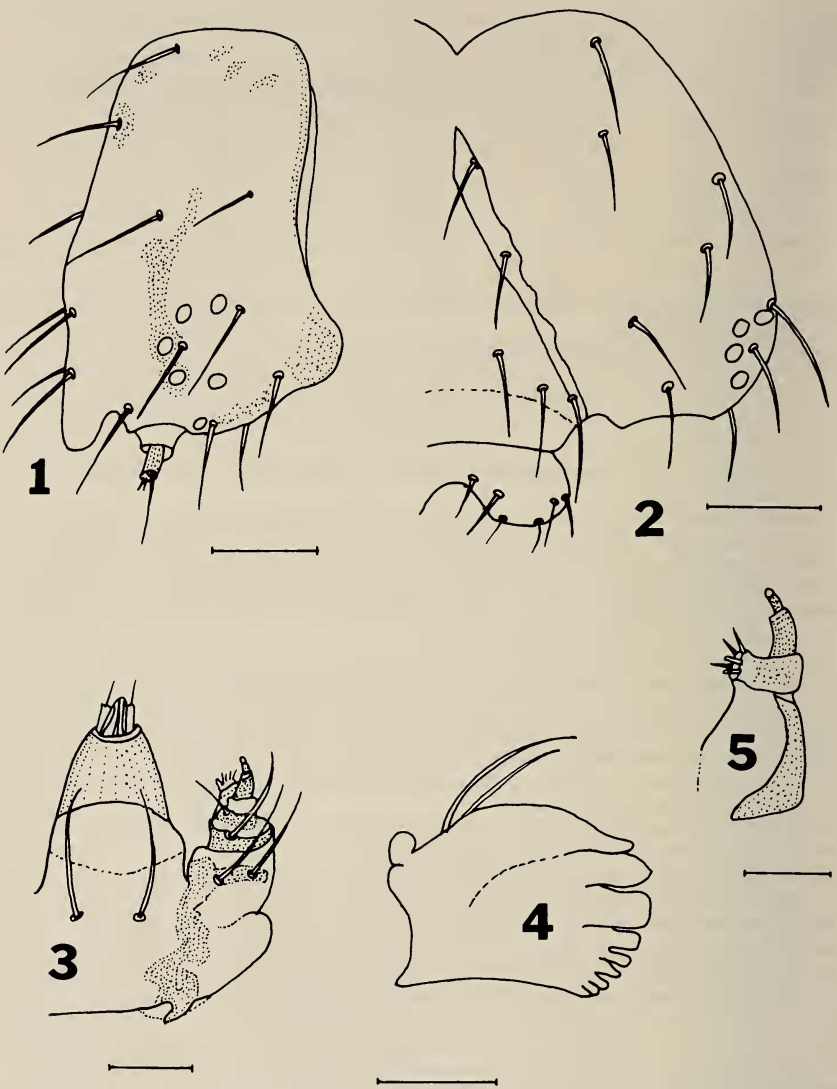
Pale form—Yellow striping more intense. Dorsal stripes broad, pale yellow with middorsal dark dashes only on thorax; only a narrow band of black above the broad yellow lateral stripe. Dashed black subventral line; legs brown with dark coxae. Cervical and anal shields yellow with brown maculations.

Yellow form with subdorsal stripe—Head paler than on darker forms. Ground color of body yellow. Dark points include only a prominent black subdorsal stripe which is continuous from prothorax through abdominal segment 10 or continuous only to abdominal segment 5, and chalazae on abdominal segments 2, 3, and 8, which are often black.

Other variations included a yellow form without subdorsal stripes; an orange form, similar to the typical form but with orange replacing yellow; a dark form with all pale patterns reduced; and a brown form.

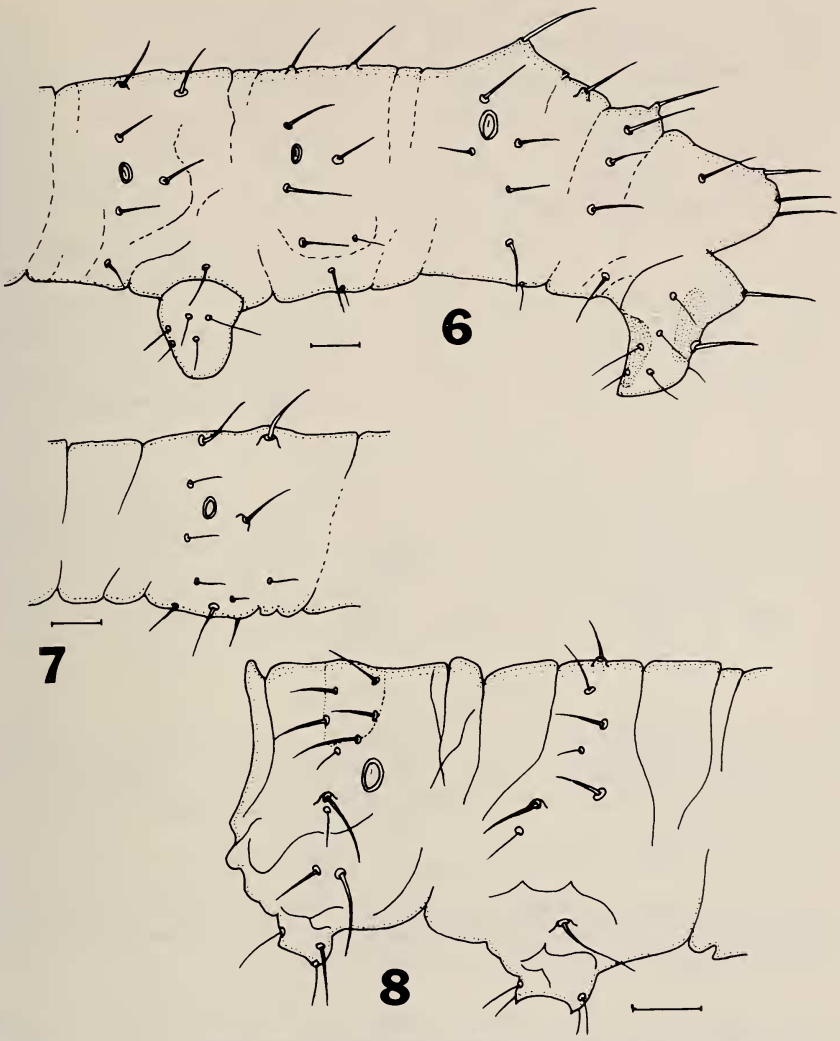
Samples of 4th and 5th instar *P. strigateria* collected at the study sites from 17 May through 8 June consisted of the forms in Table 2.

Chaetotaxy of last instar: Head with P1 somewhat in front of P2; A2 in front of and below A3 and above A1; L1 directly above 02; 01 directly posterior to ocellus 3; AF1 and AF2 widely separated; F1 almost directly below AF1 and above and in front of C2; C1 close to C2 and on edge of adfrons; labrum with L2 and M2 longer than other labral setae; 02 and C1 longest of all head setae (Figs. 1, 2). Prothorax with XD1, XD2, D1, D2 and SD2 approximately equidistant from each other; SD1 very small and close to SD2; L2 small and directly below L1: SV1 longer than SV2 (Fig. 8). On mesothorax D1, SD2 and L3 in a vertical line; D2 and SD1 anterior; SD1 very small; L2 smaller and somewhat anterior to L1; SV1 relatively long (Fig. 8). On the second abdominal segment, D2 is slightly above D1; SD1, L1 and L2 equidistant from spiracle; SD1 and L2 in front of spiracle; L1 behind spiracle; L3 below and slightly posterior to L2; SV3 behind and level with L3; SV1 below and in front of SV4 (Fig. 7). Sixth abdominal segment with D1 above D2; SD1 directly below D1 and above anterior margin of spiracle; L2 directly below SD1 and just below spiracle; L1 behind spiracle and slightly more removed from spiracle than are SD1 and L2; L3 in front of L2 (Fig. 6). On eighth abdominal segment, D1 on prominent tubercle; SD1 and D2 level with each other; SD1, L2 and L1 arranged around spiracle as on sixth abdominal segment; SV3 slightly anterior to L1; SV1 directly below SV3 (Fig. 6). Abdominal segment 9 with D1, SD1 and L1 each somewhat anterior to the seta above; SV1 posterior to L1 (Fig. 6). Segment 10 with SD1 and D1 widely separated; D2 equidistant between L1 and adjacent D2; CP1 above CP2; Lg1, Lg2 and Lg3 in vertical line; CD1 above CD2 (Figs. 6, 11). On abdominal segments 1 and 2, 1



FIGS. 1–5. *Phigalia strigateria* larval head structures. Scale line length in parentheses. **1,** Lateral view of head (0.5 mm); **2,** Frontal view of head (0.5 mm); **3,** Ventral view of mentum, hypopharynx, labial palpi, spinneret and maxilla (0.25 mm); **4,** Inner view of right mandible (0.25 mm); **5,** Ventral view of maxilla (0.25 mm).

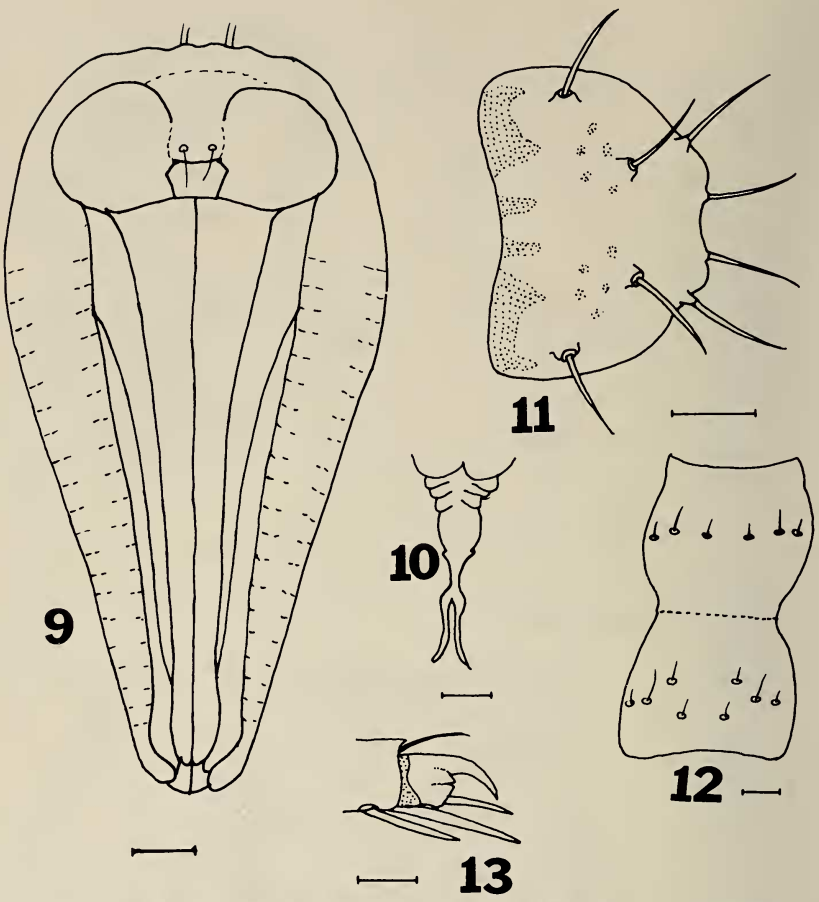
ventral seta is present; on segment 8, SV1 and SV4 closely adjacent (Fig. 12). The following chalazae are most prominent on last instar larvae: D2 and L1 on abdominal segments 2 and 3, and D1 on segment 8. Secondary setae numerous, especially dorsally and laterally on all segments; setae are fine, irregular and about ⅓ the length of primary setae. Body roughened with microspines anteroventrally on prothorax and ventrally on mesothorax.



FIGS. 6–8. *Phigalia strigateria* larva. Scale line = 0.5 mm. **6,** Lateral view of abdominal segments 6–10; **7,** Lateral view of abdominal segment 2; **8,** Lateral views of pro- and mesothorax.

Mouthparts: Mandibles with 4 large and 5 small teeth, more basal mandibular seta longest (Fig. 4); postmentum with a pair of long setae (Fig. 3); hypopharynx heavily sclerotized; spinneret tubular in shape, slightly tapering apically; labial palps almost the length of spinneret (Fig. 3); ventral side of each maxilla with 4 prominent setae, most apical one smallest (Fig. 3); terminal lobe of maxilla with 3 setae and 2 elongated papillae, apicalmost seta longest (Fig. 5).

General: Last instar about 26 mm long and 3.1 mm wide; thoracic leg claw dark brown, pointed with 1 dorsal simple seta and 3 lateral and ventral bladelike setae (Fig. 13); A6 crochets a biordinal mesoseries in unbroken band.



FIGS. 9–13. *Phigalia strigateria* larva and pupa. Scale line length in parenthesis. **9**, Pupa, ventral view (0.5 mm); **10**, Pupal cremaster (0.25 mm); **11**, Anal plate (0.5 mm); **12**, Ventral view of A1 and A2 (0.5 mm); **13**, thoracic leg claw (0.1 m).

Pupa. Reddish brown; eyes large, completely exposed, rounded; labrum hexagonal; maxillae slightly shorter than antennae; prothoracic leg extending about ⅘ length of maxilla, prothoracic femur not exposed; mesothoracic leg ending near antennae; metathoracic legs exposed beyond apex of maxillae (Fig. 9). Cremaster always bifurcate, spines usually asymmetrical (Fig. 10). Segment 7 constricted apically; abdominal segments coarsely punctate. Length similar for male and female, mean 9.9 mm (range 6.5–12) (43n); female stouter.

DISCUSSION

The chaetotaxy of mature *P. strigateria* larvae shows some variation in location of the following setae: P1 and A2 setae on head more medial than shown; L2 on abdominal segment 2 slightly before spiracle; anal plate with D2 setae closer to each other than to their respective L1's.

Comparison of *P. strigateria* larvae with those of *P. titea* from the same study areas in West Virginia showed close similarity in location of primary setae between the two species. Primary setae of *P. titea* are longer with most arising from small but well defined chalazae. SD1 and L2 on the prothorax are smaller in *P. titea* than in *P. strigateria*. Secondary setae of *P. titea* are shorter and sparser than those of *P. strigateria*. All body cuticle of *P. titea* is densely covered with microspines. Because of the marked color differences in larvae of the two species, they cannot be confused.

The pupa of *P. titea* is larger than that of *P. strigateria* (Butler 1985a). The labral shapes are more rounded than those of *P. titea*. *Phigalia titea* vertex lacks the prominent rugosity of *P. strigateria*; frontoclypeal area is smooth in *P. strigateria*, rugose in *P. titea*.

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LITERATURE CITED

BAILEY, L. H. & E. Z. BAILEY. 1976. Hortus third, a concise dictionary of plants cultivated in the United States and Canada. Macmillan, New York. 1290 pp.

BUTLER, L. 1985a. Biology of the half-wing geometer, *Phigalia titea* Cramer (Geometridae), as a member of a looper complex in West Virginia. J. Lepidop. Soc. 39: 177–186.

——— 1985b. Food plant studies for the half-wing geometer, *Phigalia titea* Cramer (Lepidoptera: Geometridae). Can. Entomol. 117:547–551.

HINTON, H. W. 1946. On the homology and nomenclature of the setae of lepidopterous larvae, with some notes on the phylogeny of the Lepidoptera. Trans. Royal Entomol. Soc. 97:1–37.

MCGUFFIN, W. C. 1967. Immature stages of some Lepidoptera of Durango, Mexico. Can. Entomol. 99:1215–1229.

PRENTICE, R. M. 1963. Forest Lepidoptera of Canada. Publ. Canada Dept. Forestry, Forest Entomol. Pathol. Br., No. 1013, Vol. 3, pp. 263–543.

RINDGE, F. H. 1975. A revision of the new world Bistonini (Lepidoptera: Geometridae). Bull. Am. Mus. Nat. Hist. 156:71–155.

TALERICO, R. L. 1968. Life history of the looper *Phigalia titea* in Virginia. Ann. Entomol. Soc. Am. 61:557–561.